Development of a Family of Picosatellite Deployers Based on the CubeSat Standard

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Abstract—Cal Poly and Stanford students are participating in the development of a new class of picosatellite, the CubeSat. CubeSats are ideal as space development projects for universities around the world. In addition to their significant role in educating space scientists and engineers, CubeSats provide a low-cost platform for testing and space qualification of the next generation of small payloads in space. A key component of the project is the development of a standard CubeSat deployer. This deployer is capable of releasing a number of CubeSats as secondary payloads on a wide range of launch vehicles. The standard deployer requires all CubeSats to conform to common physical requirements, and share a standard deployer interface. CubeSat development time and cost can be significantly reduced by the development of standards that are shared by a large number of spacecraft. In this paper the standard deployer is described along with potential variations that accommodate different mission needs.

TABLE OF CONTENTS

1. INTRODUCTION

In recent years a number of student microsatellites have been developed[1,2]. Traditionally these efforts represent a one of a kind design and require several years to complete. After completion, finding a launch opportunity is not easy, so completed satellites may wait for years to get a suitable launch opportunity.

The intent of the CubeSat program is to reduce the satellite development time to the time frame of a college student's career and leverage launch opportunities with a large number of satellites. This objective can be met through the development of a standard deployment system for CubeSats: the P-POD (Poly Picosat Orbital Deployer), developed by students at Cal Poly, San Luis Obispo. The P-POD is critical to the CubeSat program success since it must interface student satellites to launch vehicles and/or 'piggy-back' on mother satellites safely. The design of the P-POD makes it compatible with many launch vehicles as secondary, or possibly tertiary payloads. The small geometry of the P-POD allows it to interface in areas of launch vehicles that have been previously unexploited, and the low mass of a fully packed P-POD is many orders of magnitude less than mass margins set by current launch programs. Therefore, potential launch opportunities for the CubeSat program are increased.

2. The P-POD Requirements

In order to gain acceptance from launch vehicle service providers, the launch vehicle and surrounding payload safety is the primary purpose of the P-POD. In order to satisfy all requirements for launch vehicle providers as well as CubeSat developers, the design of the P-POD had to account for the following:

- The P-POD must protect the launch vehicle and other payloads from any mechanical, electrical or electromagnetic interference from the CubeSats in the event of a catastrophic CubeSat failure.
- The CubeSats must be released from the P-POD with minimum spin and a low probability of collision with the launch vehicle or other CubeSats.
- The P-POD must have the ability to interface with a variety of launch vehicles with minimum modifications and with no changes to the CubeSat standard.
- The mass of the P-POD should be kept to a minimum.
- The P-POD should incorporate a modular design that allows different numbers of CubeSats to be launched on any given mission.
- The resulting CubeSat standard should be easily manufactured without using exotic materials and expensive construction techniques.

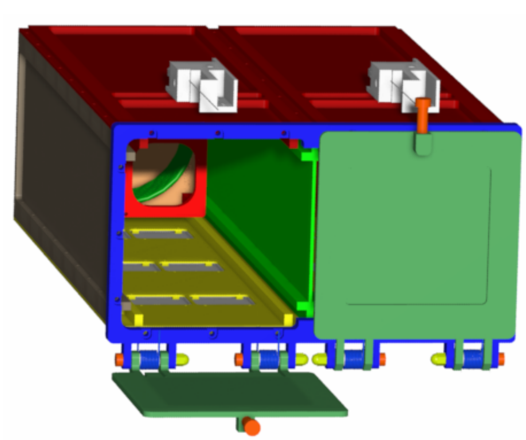


Figure 1 – Current P-POD Design

3. The P-POD Design

The P-POD shown in Figure 1 is the result of a lengthy development process by Cal Poly students and industry supporters to satisfy the requirements above. The P-POD holds six CubeSats in two parallel tubes. The tube design produces a reliable linear path for the CubeSats resulting in a low spin rate. The satellites are ejected from the tubes, using a spring plunger and travel on smooth flat rails. To prevent jamming, the interior of the P-POD is processed with a Teflon impregnated hard anodize. In addition material minimizations are external so as to leave smooth inner surfaces of the P-POD to prevent jamming in case of a possible premature antenna deployment or other unforeseeable event.

Release is initiated when the P-POD spring loaded door opens. The door is held closed by a Vectran line. To release the satellites the line is severed using a Line Cutter, designed and manufactured by Planetary Systems. The Line Cutter utilizes radiant heaters that melt the retaining line, opening the door without the shock of pyrotechnic release/separation mechanisms. The CubeSat deployment sequence is shown in Figures 2a,b, and c. The deployment concept was successfully demonstrated on a KC-135 zero-gravity test flight.

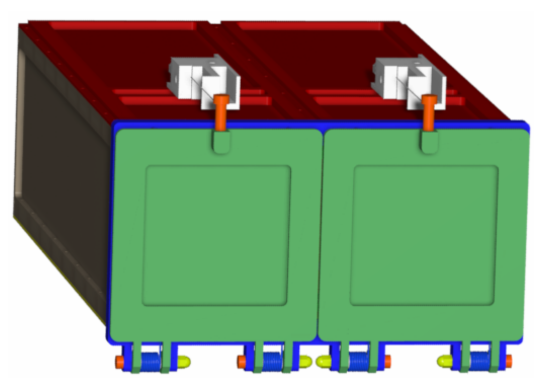


Figure 2a – Initial State of P-POD

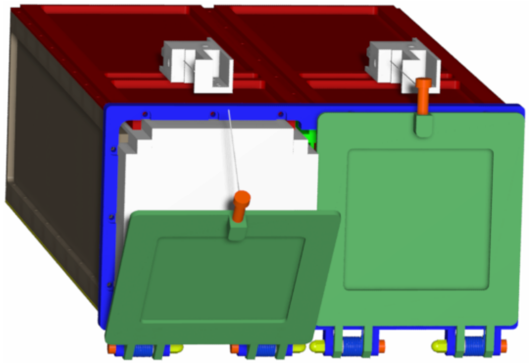


Figure 2b – Line Severed, Door Opening, Satellites Exiting

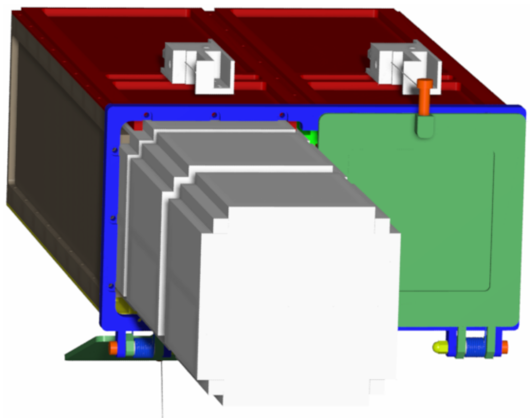


Figure 2c – Door Completely Open, Satellites Begin to Separate

The P-POD is constructed using Aluminum 7075-T73 due to its high strength, ease of manufacture and relative low cost. The deployer is designed to sustain the loading environments produced by a variety launch vehicles. The design resulted in a total P-POD mass of approximately 50% the total mass of CubeSats on board. The tube provides an enclosure strong enough to contain a structural failure of a CubeSat while providing a Faraday cage to protect the launch vehicle and primary payload from electromagnetic interference. Moreover, the P-POD is designed for maximum deflections of less than 1mm in order to prevent loading of the satellites. Figure 3a shows the finite element analysis results for a static 12g loading in all three axis, including a distributed load on the rails due to the internal satellite masses. Figure 3b shows the modal analysis results in first natural mode greater than 2000Hz, although the dynamics of the satellites have not been included.

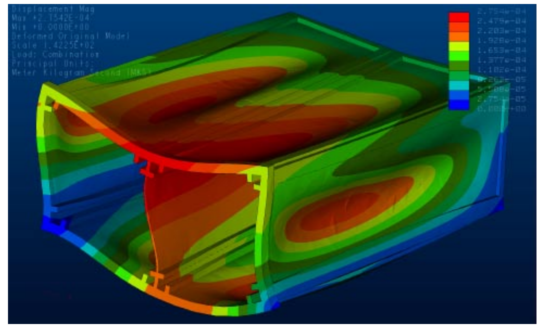


Figure 3a – P-POD Displacement Results

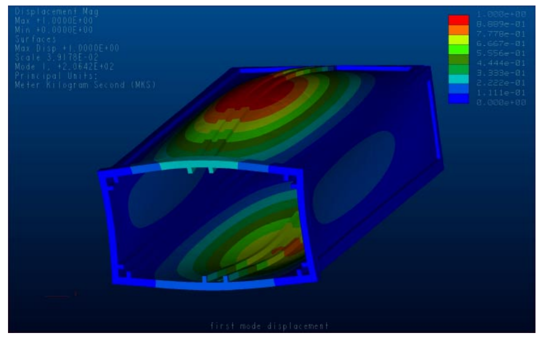


Figure 3b – P-POD Frequency Response Results

The P-POD's design allows many mounting orientations to facilitate integration to a variety of launch vehicles. The nominal mounting pattern consists of six screws along the outermost rails. The bolt pattern separation is 220mm. The spacing along the rails is variable.

A major concern in the development of the P-POD is to reduce the chances of CubeSats jamming inside the tube and failing to deploy. As a result the P-POD has a 0.6mm rail clearance around the CubeSats. On the other hand, shock and vibration loads may be amplified by this gap. Future test results will relate shock and vibration environments inside the P-POD, to launch vehicle loads.

Finally, to facilitate integration and testing of the CubeSats, access ports are located on the mounting panel of the P-POD.

4. The CubeSat Standard

In addition to the well known CubeSat size and mass requirements (10cm cube and 1kg), the design of the P-POD places additional constrains on the CubeSat developers. A smooth unobstructed area is required at the corners of the

CubeSat to slide along the P-POD rails during ejection. Other required features include a remove before flight pin, a deployment detection switch, and separation springs. These features, must be within specified areas to allow for interfacing with the P-POD and other satellites (see Figure 4). The remove before flight pin allows the satellite to be safely transported and packaged into the P-POD without activation. The satellites are activated upon detection of deployment via switches that are depressed by neighboring satellites during launch. As the satellites evacuate the P-POD, they separate using springs placed on mating surfaces between satellites. A spring plunger with a Delrin 'nose' is recommended (see Figure 5). Material processes or materials that resist cold welding are recommended on surfaces that mate with neighboring satellites. Optional features include solar panel clearance and data port access. Clearance for solar panels 6.5mm outside of the rail contact surface. The data port may be used to charge secondary cells, run diagnostics and upload software. Future plans include the ability to interface remotely with the satellites through an Internet connection allowing students to monitor the status of their CubeSat after integration with the P-POD.

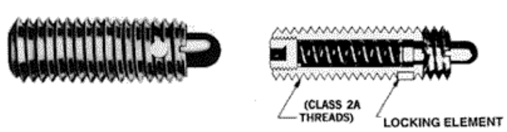


Figure 5 – Vlier[4] Spring Plunger

5. Variations on the Standard

The basic P-POD deployer contains six CubeSats, but the basic design can be easily modified to accommodate three CubeSats in a 'single barrel' configuration, see Figure 6. The single barrel design has a higher P-POD to CubeSat mass ratio since the number of sides is increased and the center divider is much thinner than the outer sides.

Without any changes in the P-POD design variations of the satellite standard are readily implemented. The nominal CubeSat length is set at 10cm, but designs have been developed that take advantage of the P-POD's length. Taylor University is currently developing a CubeSat that is twice the nominal length, or a 2XCubeSat. The 2XCubeSat is simply twice as long as a standard CubeSat, but still has the same cross section and interface requirements. A 3XCubeSat represents the current length limit The 3XCubeSat would also have the same cross sectional geometry, but the interface to other satellites such as spring plungers would not be necessary. Conversely, the CubeSat length may also be cut in half resulting in a .5XCubeSat.

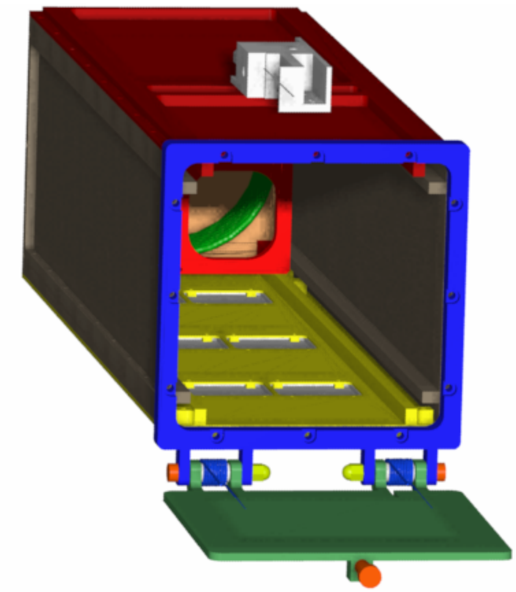


Figure 6 – 3 Capacity, 'Single Barrel' P-POD

In addition to variable length in the standard three and six capacity P-POD, a preliminary design for a Mega P-POD has also been developed that could accommodate a satellite that would be twice the width and three times the length of a nominal CubeSat, a MegaCube. To satisfy the requirements of a MegaCube, significant modifications to the P-POD are required. The center divider as well as center rails are removed to extend the capacity of the double-barrel P-POD and the double doors are replaced with a single door. Other modifications include the use of only one spring and one line cutter. However, the the Mega POD retains a standard interface with the launch vehicle. A list of current and possible CubeSat designs and some physical specifications are shown in Figures 8a-e and Table 1 respectively.

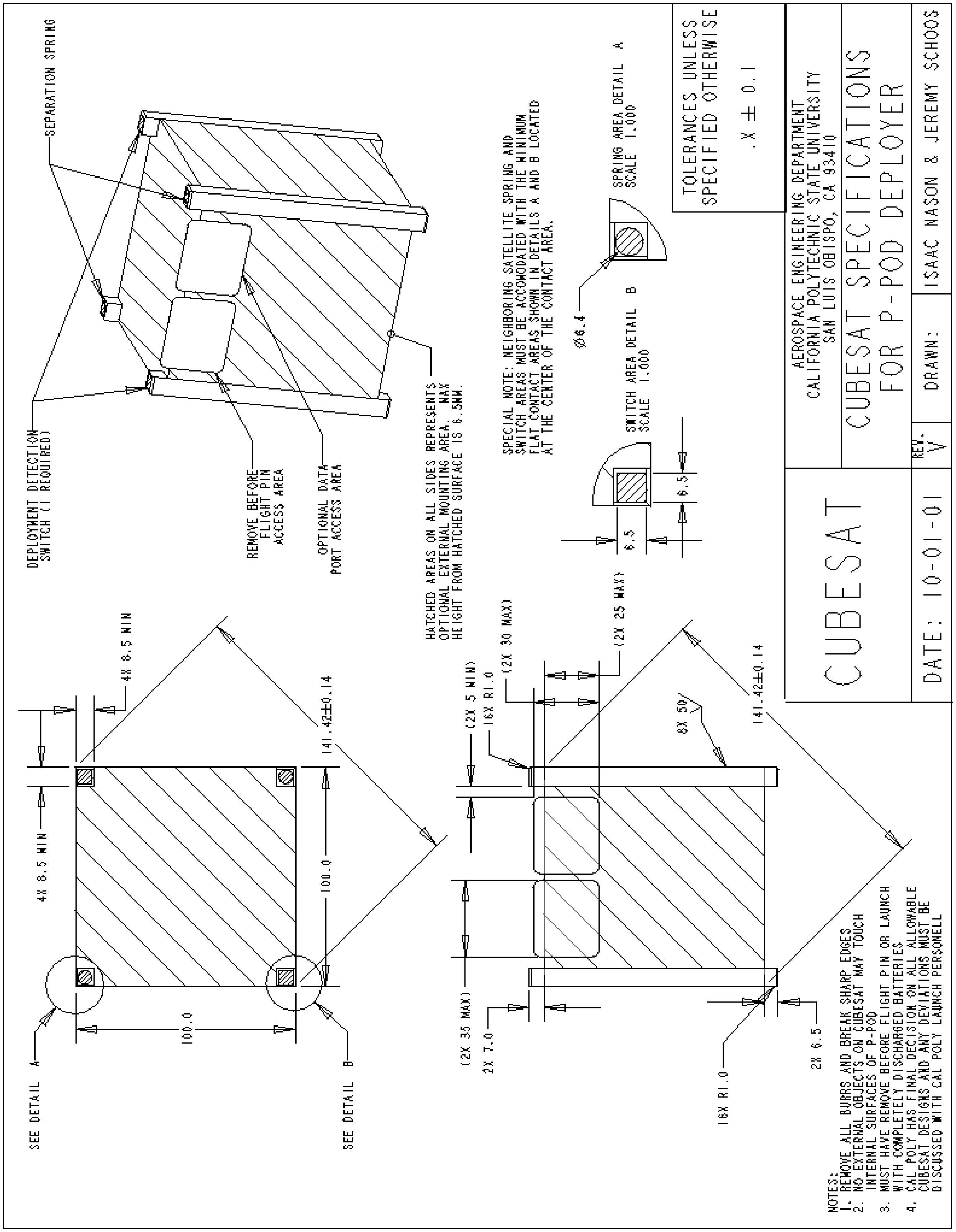
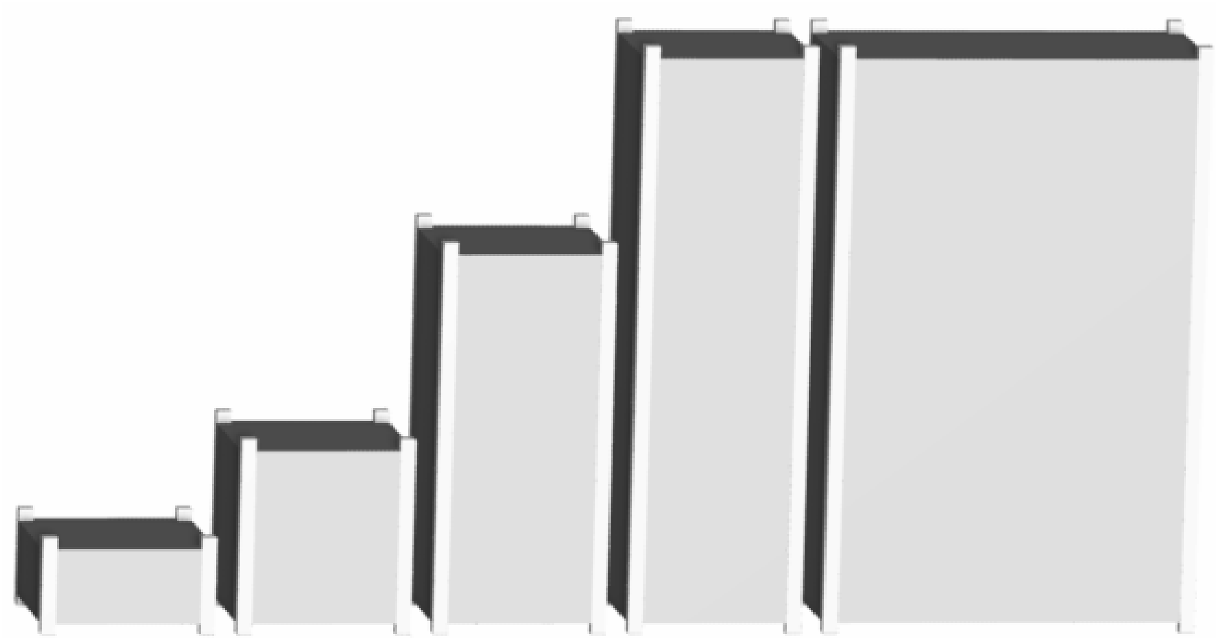


Figure 7 – CubeSat Standard



(a) (b) (c) (d) (e)

Figure 8a-e – Current and Possible CubeSat Designs

Table 1 – CubeSat Specifications

Figure	Name	Length (mm)	Mass (kg)	Cross Section (mm x mm)
a	.5XCubeSat	56.75	.5	100 x 100
b	CubeSat	113.5	1	100 x 100
c	2XCubeSat	227	2	100 x 100
d	3XCubeSat	340.5	3	100 x 100
e	Mega Cube	340.5	6	100 x 215.7

6. Launch Vehicle Interfaces

To demonstrate the P-POD's flexibility, a mumber of preliminary interfaces have been developed for a variety of launch vehicles. These include Pegasus and Delta II. Orbital Sciences' Pegasus has found space where no payload has ever flown, attached to the third stage below the conventional secondary payload area. This unusual interface would allow flight on any launch that had the necessary mass margin.

An investigation in the usual secondary payload interface for Pegasus has yielded the 6 P-POD (36 CubeSats) configuration shown in Figure 9.

Boeing's Delta II has several existing secondary payload interfaces around the avionics section below the primary payload fitting. Existing secondary payload interfaces 3 and 4, found in the Delta II user's guide have resulted in the interfaces in Figure 10.

The flexibility of the P-POD and students' willingness to work with industry will inevitably result in more launch options for future CubeSat missions.

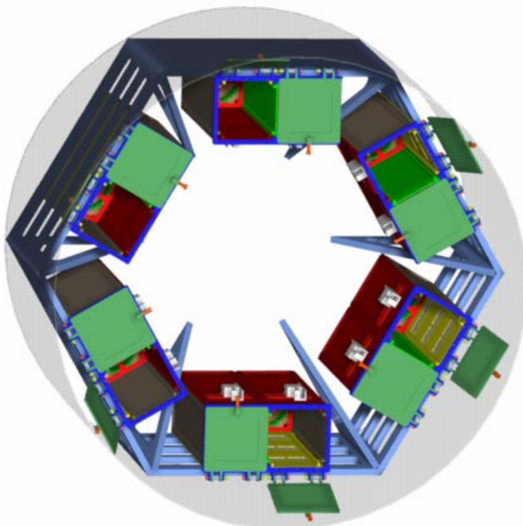


Figure 9 – Pegasus Launch Vehicle Interface

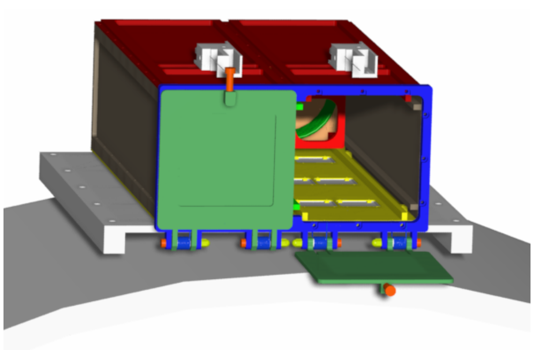


Figure 10 – Delta II, SPI4 Standard Launch Vehicle Interface

7. Conclusion

The development of the P-POD and CubeSats demonstrate the feasibility of the CubeSat standard. The CubeSat project has the potential to make space projects available to a large audience of students and professionals alike, which do not have the resources to develop large or non-standard spacecraft.

8. Acknowledgements

David Hinkley and Ernie Robinson at Aerospace Corporation, El Segundo provided knowledge and guidance consistently during P-POD development. Roger Smith, a consultant with OSSS (One Stop Satellite Solutions) provided mechanical insight and advice into the development of the P-POD at its earliest stages. Dick Daily at NASA Ames, Moffet Field generously provided his veteran expertise and resource library to help design the spring loaded hinge assembly. Walter Holemans at Planetary Systems gave much needed advice, and resources on deployment devices. TRW and Lockheed Martin and the State of California provided much needed funding for the project. Darrel Foster at NASA's Kennedy Space Flight Center Launch Services Mission Management, provided insight into the feasibility of launching on a Delta II. Likewise, Warren Frick at Orbital Sciences Corporation Launch Systems Group for his interest in providing launch services. California Polytechnic State University, and Stanford University who support not only their students, but students world wide.

9. References

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Robert Twiggs *is a consulting Professor in Aeronautics and Astronautics Department. He established the Space Systems Development Laboratory (SSDL) in January 1994 at Stanford University with both formal classes and laboratory classes for the development of microsatellites. The laboratory had its first microsatellite OPAL launched in Jon January 26, 2000. The second microsatellite SAPPHIRE will be launched August 31, 2001 on an Athena from Kodiak, Alaska. There are three other microsatellites under development for a shuttle launch in 2003. The Stanford group is now developing a picosatellite called CubeSat. This 1 kg 10cm cube will provide students in many universities with a low-cost, quick-to-launch project that will give them and other space experimenter's easy access to space. The first launches of these CubeSats is scheduled for May 2001on the Russian Dnepr ELV. Professor Twiggs received a BSEE degree from University of Idaho and an MSEE degree from Stanford University.*